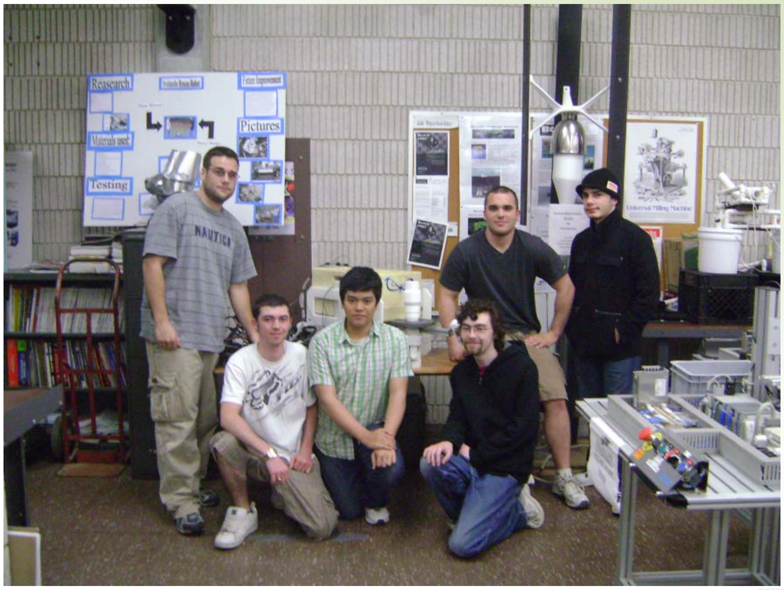
Bristol Bees

BUD-S

Bristol Underwater Disaster Solutions



<u>CEO</u>:
Ryan Kennedy
<u>CFO</u>:
Peter Mack
<u>DESIGN Engineer</u>:
Vicente Chong
<u>PROCESS Engineer</u>:
Nick Raymond, Helder Goncalves
<u>CHEMICAL Engineer</u>:
Dave Parsons
<u>ELECTRICAL Engineer</u>:
Matheus Lelis
<u>ELECTRICAL Engineer</u>:
Josh Normandin

Team Members

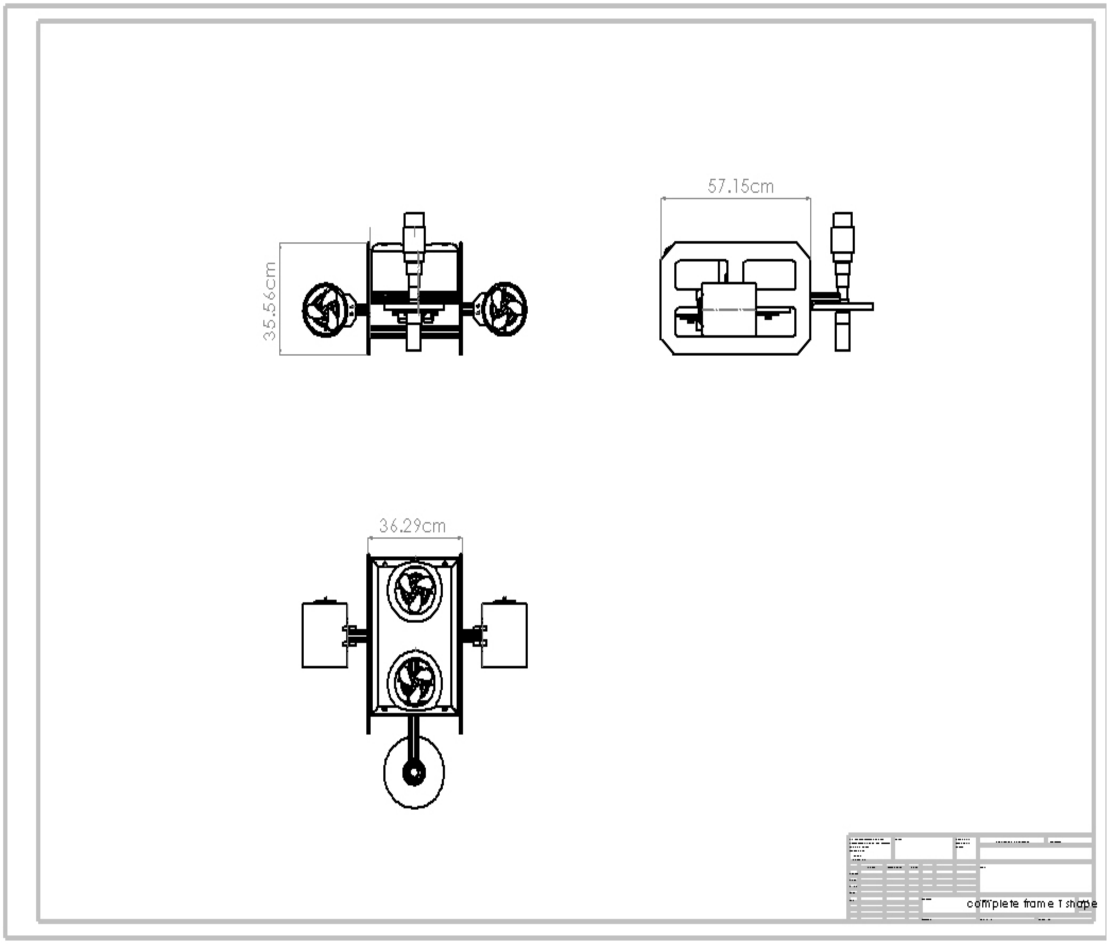
Members

Ryan Kennedy - Mechanical Engineering
Peter Mack - ELECTRICAL ENGINEERING
Matheus Lelis - ELECTRICAL ENGINEERING
Nick Raymond - MECHANICAL ENGINEERING
Josh Normandin - ENCINEERING SCIENCE
Helder Goncalves - MECHANICAL ENGINEERING
Vicente Chong - MECHANICAL ENGINEERING
Dave Parsons - ENGINEERING SCIENCE

Mentors

M. Abella-Bowen
Dr. Meyers
Patrick Mack
Al Censario

Abstract:
The purpose of this technical report is to present an accurate overview of our ROV (Remotely Operated Vehicle), BUD-S (Bristol Underwater Disaster Solutions) and the design process. Our team, The Bristol Bees, is from Bristol Community College (BCC) in Fall River, Massachusetts, USA. This is Bristol Community College's second year competing in the Explorer class. As a team we worked to create a ROV that would accomplish all of the necessary tasks in the 2011 MATE competition. For this disaster prevention themed competition our team hopes to complete all of these tasks efficiently and in a timely manner. The ROV our team has built will perform the mission while withstanding the pressures of underwater operation. In this report we will describe BUD's design as well as including the schematics we used to construct BUD. We will also share our greatest challenges and how they were overcome with some methods of troubleshooting our design. We will discuss some future improvements and lessons we learned about building and ROV and the design process. We will reflect on our project as a whole and acknowledge those who made it possible for us to be in the competition. Vital research on the nature of the project will be discussed. We will also show a budget breakdown for the entire project.



Solidworks Drawing

ROV Budget

Donations:

SMART grant donation	$3,000

Purchased Items:	Quantity	Cost	Total
HDPE White 1/2 48" x 24"	2	$55.32	$110.64
Darlex Al Extrusion	16	$13.45	$215.20
Darlex Connectors 35-1015	20	$4.00	$80.00
Darlex Connectors 35-1001	12	$4.00	$48.00
Darlex Connectors 35-1012	8	$4.00	$32.00
FIP PVC check Valve 2"	1	$21.99	$21.99
Johnson Bilge Pump Cartridges	5	$17.99	$89.95
Uwatec Depth Gauge	1	$113.32	$113.32
Micro controller	1	$84.95	$84.95
Urethane 2 part foam 16lb kit (8lb density)	1	$62.00	$62.00
Side-Power propellers	4	$41.00	$164.00
Hardware			$80.00
10lb Cast iron weight	1	$10.00	$10.00
	ROV cost		$1,112.05

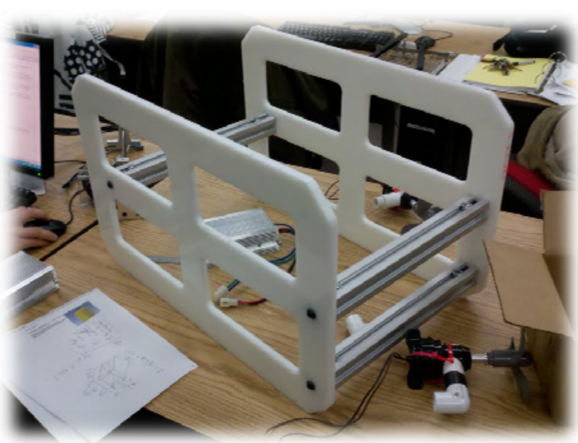
Donated Items		
Cat 5 wire		$20.00
Power Wire		$300.00
PVC pipe		$20.00
plastic funnel		$5.00
cameras		$290.00
tether flotation foam		$10.00
hb25 motor controlers		$100.00
dc to dc converters		$312.00
PS2 controller		$10.00
	Total donated cost	$1,067.00
	Total income	$3,000.00
	Total cost without donations	$2,179.05
	Total Spent	$1,112.05

Design Rationale for Vehicle Systems and Payloads:

Frame:

The ROV frame is constructed mainly from High Density Polyethylene (HDPE), and Darlex 35mm x35mm Aluminum Extrusion. The HDPE has material properties that make it great for use in underwater vehicles. It is very strong and yet still light which allowed the frame durable yet still easily maneuvered. HDPE has a Density of .95 g/ml which makes it almost neutrally buoyant in water, and it doesn't absorb water so its buoyancy remains constant even at great depths. It can last in harsh environments because it has chemical and corrosion resistance.

The Aluminum extrusion was chosen for frame cross members and as a mounting arm for the forward payloads. Darlex connectors were used which allow the ROV to be easily assembled and dissembled, and only require very few connectors to make a very rigid frame. The modularity of the Aluminum allowed for design changes to be easily incorporated and channels along the extrusion are also used to protect electrical wires connected to various components.

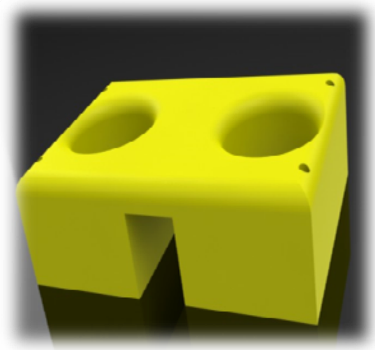


Completed Frame

Buoyancy:

For the buoyancy we chose to go with an , expanding urethane foam cap that. The foam consists of two liquids that are premixed and then poured into a mold. The use of a mold allowed us to form vertical thruster tunnels right into the foam. Mounting holes were also drilled through the foam at each corner and allow it to be firmly mounted the frame.

The foam has several properties that made it ideal for flotation and as a structural component of the vertical thrusters. A compressive strength of 250 psi ensures that the foam will retain its shape at depths far exceeding our expected operating depth. The foam also has a flexural strength (bend strength) of 350psi which allows the foam to be handled without being damaged easily. The 8lb density foam has great impact resistance while still providing 54lbs of buoyancy per cubic foot.



Foam Cap rendering

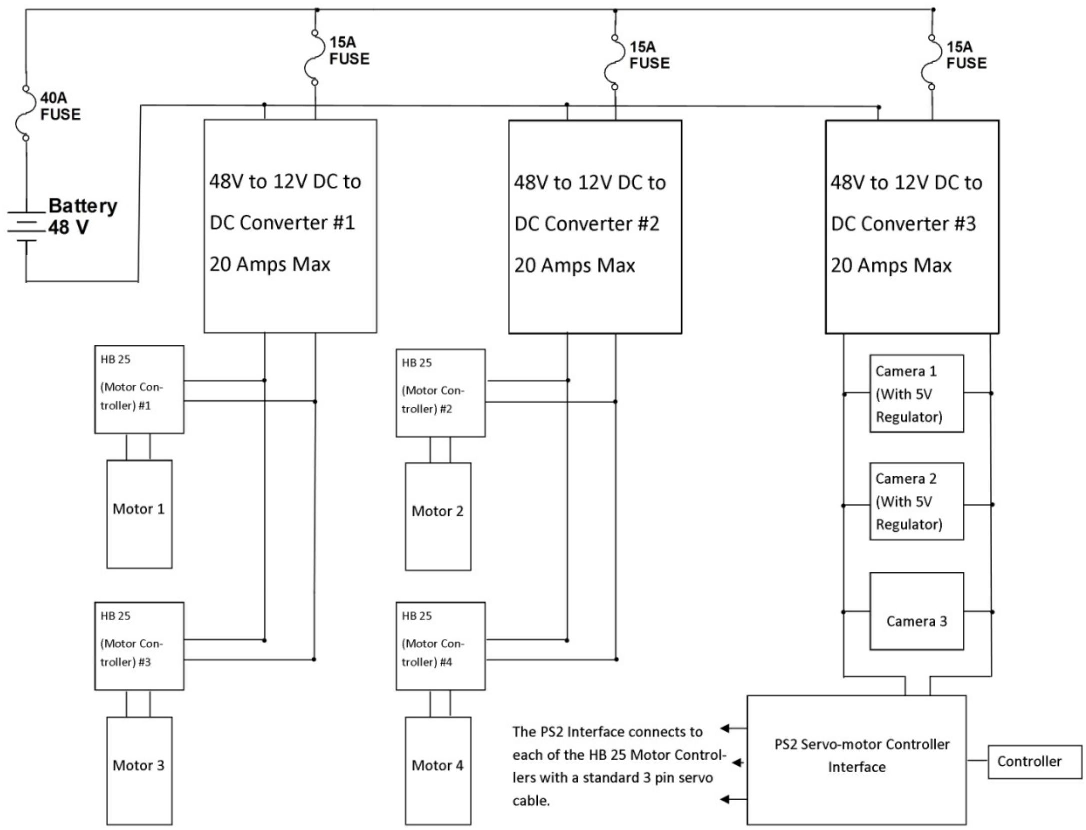
Cap Mold

Liquid Foam being poured

Completed Foam Cap

Electrical System:

Much like the rest of the electronics and motors (the affordable ones) in the world, BUD-S runs off of a 12V system. Our system uses three 48V to 12V DC to DC converters, each rated at 20A, to step down the supplied MATE power source. Each of the converters are individually fused; two with 15A and one with 7A. They are located in our watertight (tested to 15m) supply box onboard the R.O.V. The outputs from the converters are all isolated and they each have their own job. The first and second converter each power one horizontal and one vertical thruster. The current leaving these two converters will never exceed 15A. The third and final converter only powers two 5V regulators connected to cameras, one 12 volt camera, and the PS2 Servo-Motor Controller Interface. The current leaving the third converter will never exceeds 7A.

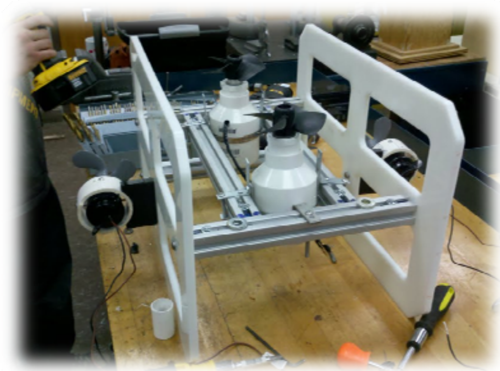


Electrical Schematic

Propulsion System:

As a result of the mission taking place at 12.2m deep, we decided our R.O.V. needed to be able to move through the water at a better than reasonable rate. BUD-S comes well equipped with four very powerful thrusters: 2 horizontal and 2 vertical. Most of the power comes from the 2 Vertical thrusters. They are made from 2 completely waterproofed (tested to 15m) 24V 135Watt Scooter motors. Each motor is capable of 2500 rpm. They sit inside of a sealed PVC housing than is made of a 76mm end cap, a 76mm to 38mm reducer, and a 102mm length of 76mm pipe. A custom made O-ring seal is the placed on the face of the motor. This seal sits firmly up against the tapper of the PVC reducer. We then put a zerk fitting on the smaller end of the tapper so the shaft could be filled with biodegradable marine grade grease. The center of the end cap has a 4mm hole which we use to fill the rest of the housing with mineral oil. When the thruster is not being serviced, the hole is blocked by a bolt. The horizontal motors are 12V Johnson 4732 LPH (liters per hour) bilge bump cartridges.

All four motors are fitted with the same 4 blade 125mm bow thruster propeller by Imtra. When submerged .6m in our testing tank and powered at 12V, the horizontal motors made 18.9 NM at 8.5A while the verticals developed 27.2NM at 3.8A each.



Control System:
The brain of BUD-S control system is the PS-SMC-06-06 (PS2 servo-motor controller interface) which is powered by the PIC16F88. This board allowed us to make driving easy for just about everyone who has ever played a videogame. It allows the pilot to have fully variable thrust in every available direction. The PIC comes with the software pre-burned and needed very little modification to be implemented with our system. Instead of powering servos, like this board was designed to do, we used to send a pulse signal to motor controllers Parallax's HB-25's. All that was changed was the refresh, maxes, and mins of the pulse cycle and the Interface worked flawlessly. The HB-25's each power one motor and operate at 12V up to 25A. The current leaving any one of the four independently fused controllers will never exceed 10A.

Tether:
BUD-S tether is comprised of 5 wires and is 25.9m long. Two of the wires are 8 gauge, they deliver power to the entire system. The other three are CAT-5 wires, one for the PlayStation controller signal feed, and the other two for video and micro-contact switch leads.

Tools and Missions:

Mission One:

This mission involves removing the damaged riser pipe. First a line is to be attached to the riser pipe and the whole riser pipe is removed from the wellhead. Then a strip of Velcro attached to a 1 ½ diameter PVC ring is removed from the damaged wellhead. Finally the entire riser pipe is removed from using manpower from the surface.

<u>Mission One Tools</u>

Velcro Hook:

The Velcro hook is a piece of aluminum rod bent into a J shape, and with a tapered point. The hook will be inserted in the PVC ring and the Velcro and ring are removed using reverse thrust from the ROV.

Riser Hook:
The riser hook is needed to secure the damaged riser pipe to a line leading to the surface. It constructed from a drywall toggle bolt that has HDPE extension pieces attached to the toggle arms. One end of nylon rope is attached to the end of the toggle bolt and the other end of the rope will be at the surface. The bolt assembly is secured to the frame by a 12V electromagnet. The assembly works in the following way:
1. The bolt arms are inserted into the u-bolt
2. Arms spring open once the pass through the U-bolt
3. The toggle assembly is released from the frame by turning off the magnet
4. The line is pulled and the arms "grab" the U-bolt
5. The riser pipe is then pulled to the surface

Mission Two

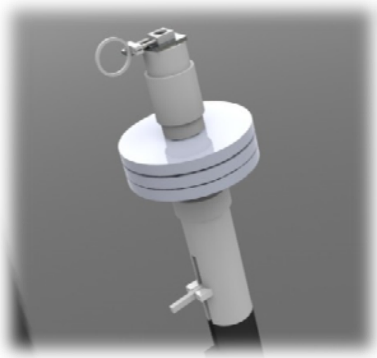
Once the Riser pipe is removed the damaged wellhead needs to be capped to stop all fluid flow. The wellhead cap will be brought down by the ROV and it needs to stay in place for until all other missions are complete

<u>Mission Two Tool</u>

Wellhead Cap:
The wellhead cap is designed to stop flow by blocking the wellhead using its own weight. The main structure of the cap is made from several sections of PVC pipe starting with a 3in. diameter at the bottom, 2in. PVC in the middle, and a 2in. PVC check valve at the top. The check valve is held open using a spring mechanism and a release pin attached to the ROV with a nylon cord. Since the check valve is held open, water is allowed to flow through the cap making it easier to position it over the wellhead. Above the check valve there's a fishing reel attached to buoyancy module made of Urethane foam. The purpose of the reel and foam is to allow the whole cap assembly to be neutrally buoyant while it's lowered to the bottom. The fishing reel has a sliding pin stopping it from rotating. The sliding pin is connected to a lever at the lower portion of the cap. Inside the pipe is a circular section of neoprene rubber which will provide a tight seal between the wellhead and the cap. The majority of mass that will stop water flow is provided by a 10lb cast iron weight that's position concentrically around the middle of the cap. The entire assembly will be attached to the ROV front mounting arm.

Here's how the Wellhead Cap works.
1. The cap is lowered over the wellhead
2. The bottom lever is pushed when the cap is lowered which releases the fishing reel release pin.

3. The buoyancy module the rises to the surface allowing the cap to fall into position on the wellhead
4. As the ROV reverses away from the wellhead the check valve release pin is pulled out
5. The check valve closes and all fluid flow is stopped



Wellhead Cap Rendering

Wellhead Cap

Mission Three:

The third mission requires us to take a water sample at a certain depth to determine if there is any oil present in the water. To determine the depth the sample is to be taken at a plot is used that shows Colored Dissolved Organic Matter (CDOM) concentration versus depth. The water sample is to be taken from a 2 gallon bucket through an opening created by a 3/4in. PVC pipe. Once the appropriate depth is found the water is sampled, the depth of the sample is recorded, and then the sample is brought back to the surface for analysis.

<u>Mission Tools:</u>

We are using a combination of a UWATEC Digital Depth Gauge and a water sampling device to complete this mission. The Depth Gauge is a standalone unit that measures depth in increments of .1m. A camera will be positioned so that the LCD screen on the gauge can be clearly read. Since the gauge runs off of an internal battery this setup provides a simple way of accurately measuring depth.

The water sampler we designed is very reminiscent of the devices used in mid air refueling. An inverted cone is attached to 1” stainless steel pipe. The metal pipe slides freely over a 1/2in PVC pipe that contains a 1/4in plastic insertion tube. One end of flexible hose is connected to the insertion tube and the other end is connected to the inlet of an In Tank Bilge Pump. The outlet of the Bilge pump is connected to a Platypus bag. The actual sampler is located on the front mounting arm, while the bilge pump and Platypus bag are mounted underneath the Foam Floatation Cap.

How the Sampler Works:

1. The inverted funnel is lowered over the sample bucket's PVC outlet pipe.
2. The top of the outlet pipe reaches the narrow end of the funnel
3. The whole funnel section slides upward.
4. As the funnel slides up the insertion tube is lowered through the PVC outlet pipe
5. The bilge pump is then turned on to siphon the fluid sample from the bucket
6. Once the sample is collected

Mission Four:

The final mission involves the collection of biological samples from the water. The biological samples are scattered throughout the bottom. There are 3 different types of organisms that need to be collected and brought back to the surface; a sea cucumber, a Chaceon crab, and a glass Sponge.

Mission four tools

To complete this mission we plan on lowering down onto the organisms and pushing them into a storage compartment underneath the ROV. A camera is positioned directly over the collection area underneath the ROV. Once the organism is completely enveloped underneath the frame a "ram" door assembly is activated. The "ram" door consists is made from wire mesh, and it slides back and forth on stainless steel rods. The door is by a bilge pump motor and a rubber drive belt that rotate a threaded shaft. The rotation of the threaded shaft is what actually moves the door forward and back. All of the samples will be pushed into a compartment lined with nylon netting. While moving from organism to organism the door will be in place over the storage compartment to prevent any organisms from escaping. The ROV then returns to the surface along with the collected biological samples.

Theme:

Background

Deepwater Horizon was an ultra-deepwater, dynamically positioned, semi-submersible offshore oil drilling rig [1]. Built in 2001 in South Korea by Hyundai Heavy Industries,[2] the rig was leased to BP plc (formerly known as British Petroleum) on March 2008. [3] Before it's demise in April of 2010, the rig was extremely successful and broke records. An example being when in September of 2009, the rig drilled the deepest oil well in history about 400 kilometers southeast of Houston, in 4,132 feet (1,259 m) of water.[4] The record breaking well had a vertical depth of 10,683 meters. [5]

The Explosion and Oil Spill

On 20 April 2010 while drilling at the Macondo Prospect, located about 60 kilometers southeast of the Louisiana coast, an explosion and subsequent fireball occurred on the rig caused by a blowout. The explosion killed 11 workers and injured 16 others; another 99 people survived without serious physical injury. The resulting fire could not be extinguished and, on 22 April 2010, *Deepwater Horizon* sank, leaving the well overflowing at the sea floor leading to an oil spill. [6] The resulting spill flowed for three months and became the largest accidental marine oil spill in the history of the petroleum industry.[7] The leak was eventually stopped On July 15, 2010 by capping the gushing wellhead.[8] This only came after about 4.9 million barrels of crude oil had already been spilled on the ocean.[9] It wasn't until September 19, 2010, that the relief well process was successfully completed, and the United States federal government declared the well "effectively dead".[10]

ROVs to the Rescue

As soon as the oil began leaking, BP employed remotely operated underwater vehicles, 700 workers, four airplanes, and 32 vessels. By April 29 they had escalated the effort and over 69 vessels, including skimmers, tugs, barges, and recovery vessels, were active in cleanup activities. [11] The tasks of the ROVs employed by BP were one and the same as the ones we have to simulate in this year's mission. They were employed to:

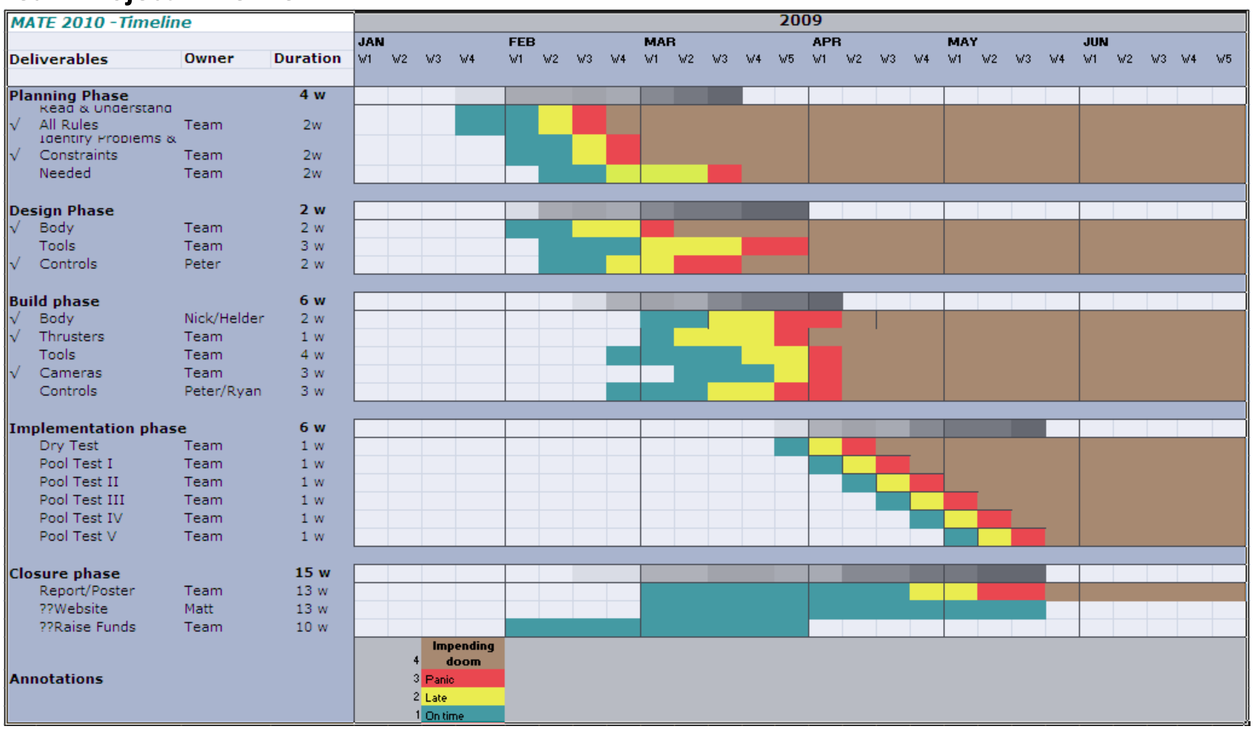
1. Remove the damaged riser pipe
2. Cap the oil well using the lower marine riser containment (LMRP)
3. Collect water and biological samples

BP used various different robots to accomplish these tasks, some that even were autonomous. The success of these ROVs relied in having a sturdy and reliable shell that could be easily modified with different tools such as the Genesis XP2500 shears or the diamond coated band saw from Cutting Underwater Technologies depending on the tasks at hand. This same approach was used by us when developing our ROV. Unlike the Venom ROV and the Shilling UHD, we decided to build a system that possessed greater vertical force then horizontal and lateral force. When it came to collect samples our water sampling tool was based on the Bluefin Robotics "Bluefin-21" AUV used by NOAA which was fitted with a "Gulper" water-sample acquisition system. Although their Gulper was a syringe-like and we chose to modify ours to use a bilge pump instead. [12]

Challenges and Lessons Learned:

One of the most difficult aspects of this year's competition was constructing an "underwater box". Its sole purpose was to protect all the very expensive components from the massive amounts of pressure the R.O.V. would face at depth. We actually debated whether or not to actually "fully test" the box because we could not afford to lose our investment. This did not prove to be an easy task the first or second time we attempted it. Our box was constructed out of one aluminum plate and HDPE. The HDPE was only used because we had extra from our frame and it was already paid for. We realize now that you should avoid this material at all costs when making a box. It is very difficult to find any glue or epoxy that will bond to it because it is a self-lubricating plastic. We pretty much tried everything imaginable and in the end resorted to a plastic welder, silicone, rubber tape, and marine grade epoxy. We now understand that it makes a lot more sense to spend a little more money to get the job done right the first time in order to save the even more valuable wasted time.

Team Project Timeline



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